U.S. Department of Agriculture
Soil Conservation Service
Engineering Division

Technical Release No. 52
Design Branch
February 1973

A GUIDE FOR DESIGN AND LAYOUT OF EARTH EMERGENCY SPILLWAYS AS PART OF EMERGENCY SPILLWAY SYSTEMS FOR EARTH DAMS

TECHNICAL RELEASE
NUMBER 52

A GUIDE FOR DESIGN AND LAYOUT OF EARTH EMERGENCY SPILLWAYS AS PART OF EMERGENCY SPILLWAY SYSTEMS FOR EARTH DAMS

Introduction

Emergency spillway systems designed by the Soil Conservation Service generally use an earth or vegetated earth spillway as a part of the system. This technical release presents rules for the layout and design of such spillways in relation to other elements of the emergency spillway system.

This guide does not treat the problem of design of rock spillways or those spillways in the transition zone between earth and rock spillways. It is anticipated that guide criteria to cover these situations will be developed after additional thought, discussion, and experience can be codified.

These guides are intended to apply principally to dams with watersheds in excess of 10 square miles.

Earth Emergency Spillways

Earth emergency spillways as discussed here include vegetated earth spillways because the principal effect of vegetation is to reduce maintenance for discharges less than the maximum. Both earth and vegetated earth spillways fail (breach) by gullying and once the gully formation and growth has started, vegetation on the earth surface has very little effect on the rate of growth or advance of the gully.

The basic concept of use of earth spillways is that they can be safely depended on to convey reasonable discharges for relatively short periods of time without breaching; i.e., releasing water from the reservoir at an elevation below the original crest elevation of the spillway. It is to be expected that significant discharges will damage such spillways. Such damage can be inexpensively repaired and if the spillway does not breach during passage of the freeboard hydrograph it will have served its basic function.

The layout and design of the total spillway system for a dam, including storage effects, must be such that it will safely pass the freeboard hydrograph. To do so each element of the system must perform its function properly. During passage of the freeboard hydrograph through the dam spillway system the earth emergency spillway will be subject to erosion attack. Resistance must equal or exceed the attack.

The Attack

The attack on an earth spillway is measured by the total volume of discharge through the spillway during passage of the freeboard hydrograph divided by the bottom width of the spillway.

Let

O_e = total volume of outflow through the earth spillway during passage of the freeboard hydrograph in acre-feet

b = bottom width of the earth spillway in feet

Then

$$\frac{O_e}{b} = \text{attack}$$

The attack may be reduced by providing additional storage between normal pool elevation and the crest of the emergency spillway or by increasing the capacity of the high stage of a two-stage principal spillway or by both. These methods not only reduce the attack on the earth or vegetated emergency spillway where it constitutes the whole of the emergency spillway system; they also reduce the frequency of operation of the emergency spillway and, hence, may have a material effect by reducing the maintenance and repair costs on such spillways. The attack may also be reduced by increasing the width of the earth emergency spillway.

Both of these variables should be included in cost studies of various layouts to arrive at the least costly and most practical overall layout that will function as required. Such studies should be made in the planning stage to avoid land rights complications and changes at the design stage.

Resistance

Resistance to erosion and gullying is measured by the erosion resistance of the soil and the bulk or amount of soil that must be eroded to produce breaching of the spillway. Soils are divided into two broad classes to evaluate their resistance to erosion.

Easily Eroded Soils (E) are:

1. Cohesionless soils or soils with low plasticity index, I_p, not greater than 10; such as, SP, SW, SM, ML, GP, GW, and GM.

2. Recent alluviums, colluvial soils, most organic soils, and other soils with a low density. Soils with a void ratio (in place) greater than 0.7.

3. Dispersed soils, soils easily dispersed, and clay soils with a moderate to high shrink-swell potential ($I_p > 40$).

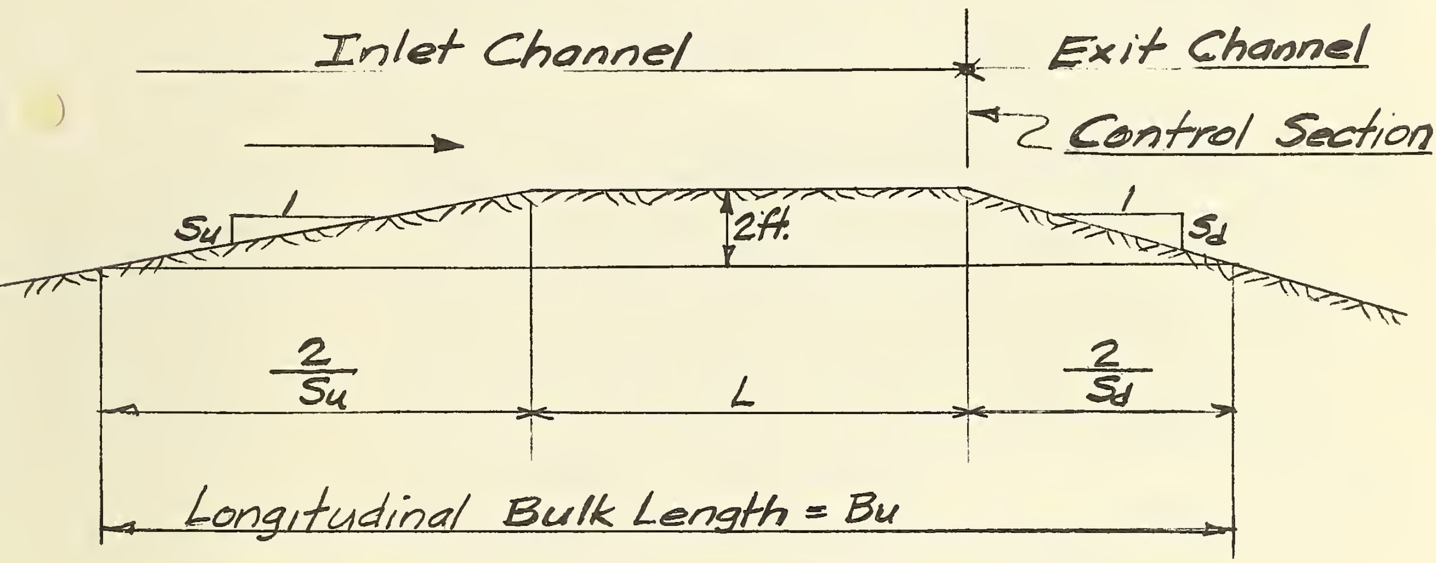
4. All other soils not in Erosion Resistant Soil (R) group.

Erosion Resistant Soils (R) are:

Cohesive soils with an I_p between 10 and 40 and a void ratio (in place) equal to or less than 0.7.

The most erodible soil at any location beneath the bulk length in the earth or vegetated spillway to a depth of 30 feet or to the base of the dam, whichever is least, is to be used to determine the soil class for the earth spillway.

The longitudinal bulk length of the earth or vegetated spillway, B_u, is defined by the sketch below of a section through it.



$$B_u = L + \frac{2}{S_u} + \frac{2}{S_d}$$

L = length of level section of spillway in ft.

S_u = slope of upstream part in ft./ft.

S_d = slope of downstream part in ft./ft.

The effective bulk length of an earth spillway may be increased by installing barriers that will effectively stop the head cutting in a gully advancing toward the point of breaching of the spillway. To accomplish this, such barriers must penetrate into or be supported by massive nonerodible rock or other very erosion resistant material; they must be structurally stable against overturning and sliding and so designed as to prevent flanking (end around erosion). The design of such barriers should be checked with the EWP unit.

<u>Resistance ≥ Attack</u>

The resistance to breaching must equal or exceed the attack or the earth spillway will fail. The following empirical formulas express the relationship between resistance and attack.

Let

I_p = plasticity index in percent

B_u = longitudinal bulk length in feet

<u>For Class R Soils</u>

$$\frac{O_e}{b} \leq \left[I_p + \left(\frac{B_u - 300}{20} \right) \right]$$

where the following limits are not exceeded

$$\frac{O_e}{b} \leq 50 \text{ ac. ft. per ft.}$$

$$10 < I_p \leq 40$$

$$B_u \geq 100 \text{ ft.}$$

<u>For Class E Soils</u>

$$\frac{O_e}{b} \leq \left[\frac{B_u - 100}{50} \right]$$

where the following limits are not exceeded

For $5 < I_p \leq 10$

$$\frac{O_e}{b} \leq 20 \text{ ac. ft. per ft.}$$

$$B_u \geq 300 \text{ ft.}$$

For $I_p \leq 5$

$$\frac{O_e}{b} \leq 10 \text{ ac. ft. per ft.}$$

$$B_u \geq 300 \text{ ft.}$$

Layout

The layout of earth emergency spillways must meet certain requirements if they are to function properly. These rules are:

1. The layout must be such that the energy loss through the inlet, from the reservoir to the control section, along any flow line, is equal. This is necessary to insure that the discharge per foot of width across the control section is the same for the full width of the spillway.

2. The crest of the spillway should be level within $\pm$ 0.1 foot.

3. The constructed exit channel must be straight and extend sufficiently far that its end is downstream of the toe of the earth dam embankment.

4. The width of the earth spillway should be divided into segments that do not exceed 200 feet in width. These segments must be divided by dikes which extend from the upstream end of the level section to the downstream end of the exit channel and have a height at all points along its length which is sufficient for the top of the dike to be at or above the maximum water surface elevation attained during passage of the freeboard hydrograph at all points. These dikes should have a minimum top width of 10 feet, minimum side slopes of two horizontal to one vertical, and a constant base width to maintain a constant bottom width for each segment of the spillway.

5. The slope of the exit channel should be such that an hydraulic control section will exist at its upstream end for all discharges above 0.25 times the peak discharge rate attained during passage of the freeboard hydrograph.

6. Crest control structures used to increase effective bulk length should be located near the upstream end of the level section of the earth spillway.

7. Sufficient lateral bulk must exist between the earth spillway and the gutter at all points along the spillway to protect the gutter and the earth dam embankment. Consider any cross section normal to the centerline of the earth emergency spillway along its constructed length downstream of the projected centerline of the earth dam embankment. Each such cross section should meet the following requirements:

    a. The side slope of the spillway channel on its side nearest the earth dam embankment should be three horizontal to one vertical.

    b. If a dike is required to confine the maximum possible discharge in the spillway the following requirements should be met:

        (1) The top elevation of the dike, at each cross section, should be at or above the calculated water surface profile for the maximum possible discharge.

        (2) The top width should be at least 12 feet.

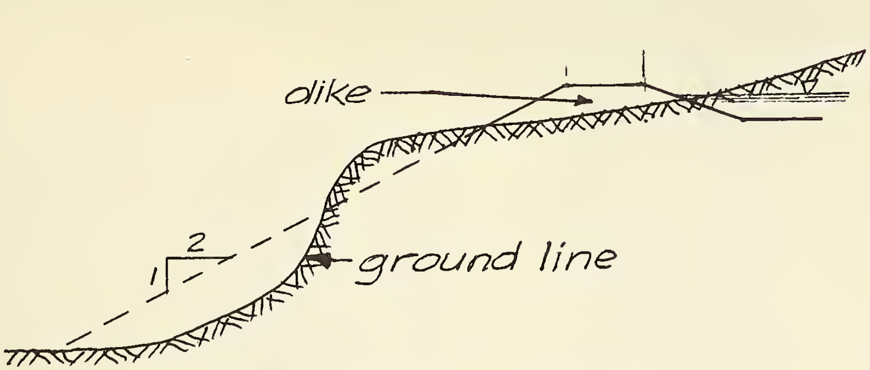
        (3) A line, in the plane of the cross section, with a two-to-one slope projected downward from the toe of the dike at its edge nearest the embankment should not be above ground at any point.

    c. If at any cross section a dike is not required to provide freeboard as stated above, the final ground line at all points should be coincident with or lie above a hypothetical cross section as defined above for the situation where a dike is needed.

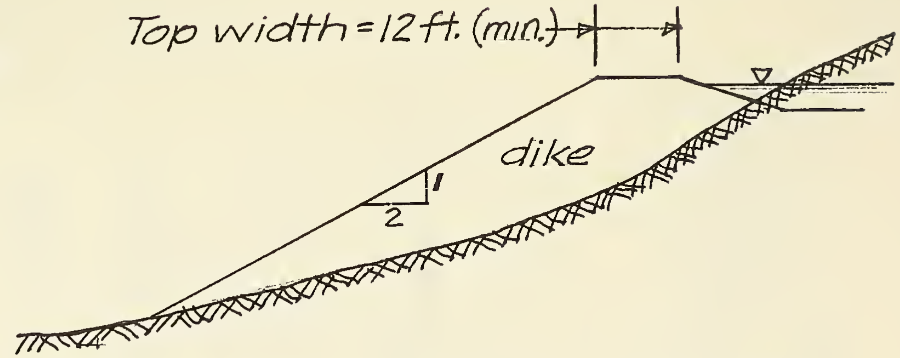
    These requirements are illustrated by the sketches on the following page.

Emergency Spillway Systems

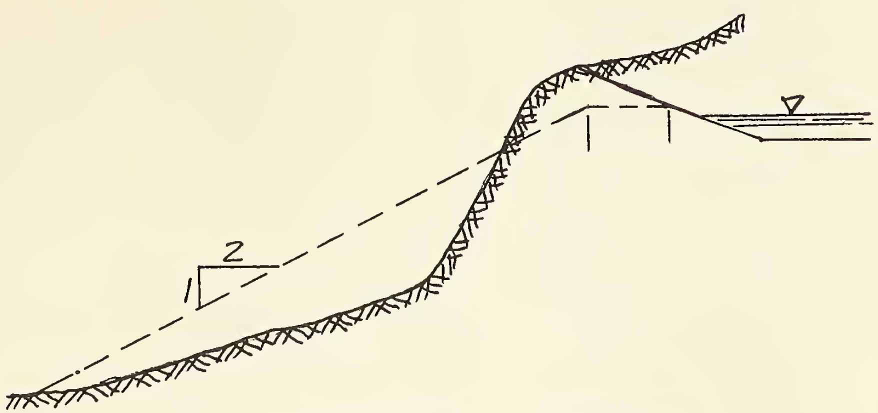
These criteria for earth emergency spillways will, in the larger watersheds, necessitate the use of emergency spillway systems that differ from those used on smaller watersheds. These systems may consist of two-stage reinforced concrete drop inlets, reinforced concrete chutes or large reinforced concrete culvert type spillways with reinforced concrete chute outlets all with or without earth spillways as a component.



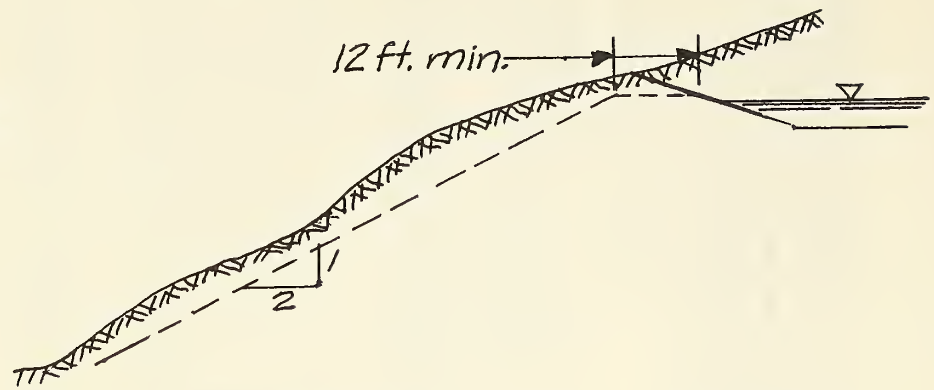
Not Acceptable



Acceptable - Not Desirable



Not Acceptable



Acceptable and Desirable

The emergency spillway system will be discussed in terms of a primary emergency spillway and a secondary emergency spillway. This functional notation differentiates between spillways as to the elevation of their crest; i.e., the order or sequence with which they come into operation during passage of the freeboard hydrograph.

Primary Emergency Spillway

The primary emergency spillway will come into operation first because its crest elevation is lower than that of the secondary emergency spillway. The primary emergency spillway might be:

1. An earth or vegetated emergency spillway. In this case there would be no secondary emergency spillway.

2. The high stage of a two-stage principal spillway. In this case there would usually be a secondary emergency spillway of the earth or vegetated spillway type. In some cases on dams on smaller watersheds at sites where excavation of an earth or vegetated spillway would be very costly this primary emergency spillway might be used alone to pass the freeboard hydrograph if sufficient storage were available within legal limits to make such a layout economical.

3. A reinforced concrete chute located in or on an abutment or topographic saddle, either with or without a secondary emergency.

In PL 566, the floodwater detention capacity of any single structure may not exceed 12,500 acre-feet and this establishes the maximum elevation of the primary emergency spillway. Token spillways are not permissible. There should be no restriction on the rate of discharge of the primary emergency spillway imposed by the downstream benefited area. Normally the minimum capacity of the primary emergency spillway should be several times the capacity of the principal spillway. All planned flood prevention objectives must be met before the reservoir stage reaches the crest of the primary emergency spillway.

Closed type primary emergency spillways such as the drop inlet or culvert with chute outlet can differ materially in their potential for clogging by debris depending upon the type of trashracks provided. Drop inlet spillways with a standard two-way covered top inlet should have a minimum unobstructed cross-sectional area of each opening of the barrel of 40 square feet. All other closed type primary emergency spillways should have a minimum cross-sectional area of each unobstructed opening of 80 square feet. The ratio of the width (W) to the height (H) of the unobstructed opening, in both cases, should be equal to or greater than 0.75 and equal to or less than 1.33.

Secondary Emergency Spillway

The secondary emergency spillway will come into operation after the primary emergency spillway and its crest elevation will always be at a higher elevation than that of the primary emergency spillway. The secondary emergency spillway will almost always be an earth or vegetated emergency spillway.

Hydrology

Criteria presented in "Engineering Memorandum No. 27 (Rev.), Section C - Hydrologic Criteria" are to be used to develop the freeboard hydrograph used in conjunction with the above criteria for the design of the emergency spillway system. Paragraph I-A, Structures in Series, of the above reference is especially pertinent in this situation.